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Micronutrient strategies for marginal areas.

Abstract.
Micronutrient deficiencies in human nutrition, especially of iron and zinc, occur often in marginal mountain regions. The main cause is poverty, resulting in low nutrient diets. Poor nutrition is one of the main causes of major health problems, especially among children. However, micronutrient deficiencies are also widespread in the farming systems of the mountains, leading to depressed crop yields, and reduced nutrition quality of staple crops. Balanced crop nutrition can at the same time improve crop yields, economy and nutritional quality. Micronutrient disorders is a peculiar and complicated set of problems, and dealing with it requires strategies which take into consideration a range of problems regarding farming systems, knowledge, extension service, technology transfer and economics. The paper presents a discussion of different strategies.

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The nutrition problem.
Over the last two decades, increasing attention has been directed towards specific deficiencies of trace elements such as iodine, iron, zinc and selenium in human nutrition. Brown & Wuehler (2000) estimated that 95.4 % (+/- 2.1) of the population in South Asia are at risk of low zinc intake, compared to 71.2 % (+/- 14.2) for Southeast Asia. In USA and Canada, 0.9 % (+/- 0.2) of the population is found in this category. The zinc status of individuals is difficult to determine. A good indicator of zinc deficiency at cohort level is the frequency of *stunting* - the proportion of the population which is more than two standard deviations below normal height-for-age. In Nepal, various sources estimate this figure to be around 50-60 %. In addition, an even larger proportion of the population suffer from latent deficiencies, increasing the frequency of various subtle or irregular zinc deficiency disorders. It is estimated that 2.1 billion people, one third of the global population, are iron-deficient (Bouis et al. 1999).

Mineral deficiencies have multiple effects, from general fatigue and immune system defects, to severe damages of brain and other organs. Brown (1990) presented a comprehensive outline. Intervention trials with zinc and vitamin A in South Asia have demonstrated dramatic reductions of prolonged diarrhoea and respiratory infections in children (Black & Sazawal 2001; Bhandari et al. 2002). Interactions between minerals and vitamins do occur, and it is important to deal with the major deficiencies (iron, zinc and vitamin A) simultaneously (Gibson & Ferguson 1998).

There are several reasons for deficiencies. The general problem in poor populations is lack of purchase power for nutrient dense foodstuffs (animal protein, vegetables) which would have been desired if the income level was sufficient. Therefore, the ultimate solution is social development for the poorest groups in the society. Dietary choices do, however, also express local taste and tradition. Therefore, the poverty-to-nutrition relation is not quite simple, and low-cast or out-cast groups may have better nutrition than predominantly vegetarian high-cast groups.

The most important problem with respect to zinc and iron is the consumption of foods that are high in the *inhibitors* phytic acid and fibres. Phytic acid is a natural organic phosphate compound notably found in the endosperm of seeds. This affects ‘poor mans proteins’ - pulses, and wholegrain cereals. The best source of zinc is red meat and animal proteins in general. The worst diet is a combination of a low nutrient density staple such as rice, and a limited amount of pulses as source of protein, for instance the Nepalese *Dal Bhat* (rice and lentils). *Promoters* are food items or compounds such as ascorbic acid (vitamin C) that are enhancing bioavailability. Phytic acid content may be affected by processing (milling, germination, soaking; see below).

Finally, soil fertility may impact plant nutrition to an extent which affects yields as well as nutrient content of the crops. Zinc is deficient in about half the agricultural soils in India, and about one-third of China (White & Zasoski 1999). In Himalaya, insufficient mapping has been done, but there are indications that about 30-50 % of all soils are deficient in zinc, and 85-90 % in boron (Andersen 2002). Although soil/plant deficiencies often are less important than trade, social conditions and preferences in a local human nutrition perspective, there is tremendous scope for ‘shifting the distribution curve to the right’ through agricultural intervention as expressed by Bouis et al. 1999 in a discussion of iron deficiency.

Strategies for improving human micronutrient nutrition.

In a review, Gibson & Ferguson (1998) divide intervention strategies into *supplementation, fortification and dietary modification/diversification.* In their view, integrated approaches should be applied, using relevant strategies in combination.

Supplementation may be used for targeted groups, needing an improvement in zinc status over a short time. However, uncertainties exist about choice of zinc compound, and supplementation requires a considerable system for control of regular supplies as well as intake. Therefore, marginal groups in marginal areas are least likely to benefit from such a programme. Mountain dwellers will often be found among these groups. While vitamin A can be supplied by mega-dose intervention, the use of minerals requires stable supplies.

Fortification is dependent on the existence of an appropriate ‘vehicle’, an option which differs between elements, and between regions. As an example, iodization of salt is probably the most appropriate choice for that element; the challenge is to exert a reasonable control over the salt supplies. In areas where purchased wheat is a staple, iron fortification of flour is a cost-effective solution, and programmes aimed at small scale, local mills may be an option. For zinc in rice- (or sweet potato-) based diets, no obvious food processing solution presents itself, but *bio-fortification* has been proposed as one option (Bouis et al. 1999). This option has received substantial interest within the CGIAR (Consultative Group on International Agricultural Research) system, and research programmes are currently undertaken at the specialised centres IRRI (rice, the Phillipines) and CIMMYT (maize/wheat, Mexico). A major part of the research based on GM (Genetic Manipulation) techniques. In principle the same achievements may be reached through plant breeding when development is dealing with uptake efficiency or availability in the crop, whereas the strategies aiming at plant synthesis of for instance vitamin A (‘golden rice’) do require genetic manipulation.

Three major bio-fortification strategies are looked into:

-Increased nutrient density
-Anti-nutrient reduction
-Increase enhancers

Increasing nutrient density relies on the assumption that the soils in general hold large amounts of nutrients which are unavailable to crops in general, but can be extracted by *micronutrient efficient varieties*. Screening for efficiency has taken place for some crops. Subedi (2000) quotes research from the Phillipines where replacement of ‘farmers’ varieties’ with ‘selected cultivars’ gave an advantage of 2.6 t/ha of rice grown on zinc deficient soils.

The assumption that there are large reserves of geologically bound minerals available which only need an efficient plant to release them may be valid for some nutrients on many soils, and it may be valid for zinc on mineral soils in general. However, the principle is not bound to hold for all nutrients on all soils, and the lack of for instance boron and selenium may be too pronounced in large regions in Asia even for efficient varieties to work, in particular on sandy soils, or highly weathered tropical soils. Thus, when Bouis et al. (1999) put ‘deficient soils’ in quotation marks, it has a rhetoric element; if all other crops are affected by low nutrient content, the results of the efficient variety is with the plant, not the soil.

One major problem with breeding for efficient varieties is that multiple soil deficiencies is the rule rather than the exception. Among plant breeders, it appears to be a problem to breed varieties which take several deficiencies into consideration, but it is unlikely that a zinc-efficient variety will gain broad acceptance in areas where effects are small because there also is a boron deficiency. This is not least a problem with wheat breeding, because CIMMYT not yet is prioritising boron efficiency in their work (Rerkasem 2002), and not even screening the released varieties for susceptibility to boron deficiency.

Another problem for plant developers is whether the increased micronutrient density is found in the edible/eaten part of the grain, or if it is located in the endosperm and is removed in a milling process.

Anti-nutrient reduction is mainly aimed at reducing the content of phytic acid, which is genetically controlled. Some cautionary voices have been raised against this strategy. Firstly, phytic acid is there for some reason. It is the main storage of phosphate in the seed, and reduction of the content may reduce germination abilities or other important aspects of the crop. Secondly, phytic acid is a human nutrient itself, involved in the supply of phosphate compounds.

Increase of enhancers may include breeding of varieties with higher content of ascorbic or other acids, or phytic acid-splitting enzymes (phytase). A challenge to this strategy is to select plants with enhancers that are thermostable enough to be unaffected by cooking preparations.

All bio-fortification strategies must live up to farmers' and consumers' expectations for yield, as well as taste, look and odour. But if they do, plant breeding is probably the most cost-effective way of improving micronutrient nutrition in low-income areas.

Dietary modification/diversification. Various options exist to enhance micronutrient availability through processing. The problem of phytic acid can be reduced by soaking, germinating or fermenting various staple grains, and substantial results can be achieved if these techniques can be promoted in a manner which is consistent with local taste; an example from Malawi was reported by Gibson & Hotz 2001.
The effects of germination are especially beneficial, as it leads the seed to 'unpack' all its stores of minerals and other nutrients in forms which are available to the plant, or the consumer.

An increase in the consumption of flesh foods (including small fish, grubs, grasshoppers and other locally available alternatives) is in many respects the best way to reduce micronutrient deficiencies, as it also affects supply of protein, fats and vitamins. It does, of course, depend on the availability of such food items. Furthermore, it is always difficult to change dietary habits. Decades of propaganda efforts in western countries with good information channels and adequate provision of nutritious foods still has a long way to go, and the task is far more difficult in economically and geographically disadvantaged populations in marginal mountain areas. Ethnically or religiously based food taboos may play a role too, for whole groups, or when it comes to intra-household distribution of certain foodstuffs. Gittelsohn et al. (1997) found that adult women are disfavoured when allocating micronutrient-rich food items in rural Nepali households.

Fertilisers and micronutrients.
An efficient application of fertilisers requires specific knowledge of crop and soil requirements. In a traditional understanding of agricultural extension, there should be a close interface between farmers and agronomic advisors. FAO/IFA (2000) presents a scenario for farmers in homogenous plain areas, where blanket recommendations can be issued from one extension officer to for instance 2-3 000 farmers. For mountain areas, where soil conditions are more complex, another scenario is presented, requiring extensive soil testing and one extension worker per 500 farmers. In reality, the number of extension workers is much lower in marginal mountain areas than in the plains. According to Blaikie & Sadeque 2000, the JT/JTA (Junior Technician/Junior Technical Assistant) system in Nepal is not only seriously understaffed, but also there is a great need for skill upgrading, and the staff has to respond to inconsistent policies. Very few farmers are having their soils analysed. The extension messages and the deliveries of inputs to most Nepalese Hill farmers are simple to the extreme. They are applying chemical fertilisers which contain nitrogen only (Urea) or nitrogen and phosphate (DAP).

A number of compound and single element micronutrient fertilisers are available in the Nepalese market (STSS 2000), but except for a limited use of zinc compounds on rice in Terai, they are predominantly applied as a *vitamin* in market-oriented vegetable production in limited areas. This means that the effect on human nutrition at present is negligible. In addition, several of the compound micronutrient fertilisers are high-grade mixtures diluted in water for spray application, and sold at prices which do not make them cost-effective in staple crop production. The use of single element fertilisers such as zinc sulphate (oxide or chelates) or borax, could be the most cost-effective way of balancing plant nutrition. This would, however, need improved technical knowledge among the farmers. Soil testing is available at subsidised rates from STSS, but should be supplemented with knowledge on *visual symptoms* of micronutrient deficiencies.

However, it still has to be proved that the mountain situation in fact is too complicated for blanket recommendations. The overall pattern of Himalayan soils appears to be deficiency in boron almost everywhere, but no high values. Hence, for boron there is a clear scope for testing out blanket recommendations. Soil concentrations of zinc vary in a pattern which appears to be geologically determined, and 3-5 % of soil samples in Middle Hills in Nepal as well as in Himachal Pradesh are high in zinc (Andersen 2002). This presents a risk of zinc toxication of soils if zinc added fertilisers are used for blanket recommendations. The risk may be theoretical, as zinc toxicity normally only occurs at very high concentrations around metal working factories or mines. But still, if a too large proportion of the soils do not give any yield responses to compound micronutrient fertilisers, the costs involved can not justify the action.

Interestingly, a major trial of the effects of blanket recommendations of micronutrient fertilisers has already been undertaken in Nepal. Finnish development aid and research had a long term involvement in soil fertility in Nepal. On the research side, some of the general background presented in a global study on soil fertility (Sillanpää 1982), followed by intervention studies in Nepalese research stations (Tripathi & Shah 1986). FINNIDA , the national Finnish development aid organisation, was during a period directly involved in provision of subsidised fertilisers to Nepal (an approach which now probably is seen as outdated (FAO/IFA 2000)).

An unpublished mapping project carried out by Sippola & Lindstedt 1994 showed that there were widespread deficiencies of boron and zinc in the soils in a large area east and west of Kathmandu. On the basis of these findings, two fertilisers were formulated, one for general crops: N:P:K:S:B:Zn ratio of 20:4:5:2:.03:.1 and another for rice: 20:6:10:3:05:.3. An unknown quantity of this fertiliser was produced by the Finnish company KEMIRA and shipped to Nepal. The rest of the implementation of the project is undocumented, but appears to have been as follows: It was the understanding by the Finnish side that a revolving fund should be established, in order to plough back income generated from fertiliser sales to purchase of new supplies. However, Ministry of Finance in Nepal failed to establish this fund, and the income 'went into some different projects' (Shrestha, pers. comm.). As a result of this, the donor was discouraged from further involvement and the project was terminated and never evaluated. It is said that the farmers were extremely happy with the results they had from using the fertiliser, but this information as well as the final history of the project comes, sadly, from sources outside the Nepalese State system.

The end result is that 10-15 years of research and assistance went down the drain, without being embedded in the 'institutional memory' in Nepal or Finland. Since the technical implementation of the programme did not encounter any problems (except for the cost of high-grade, imported fertiliser), and it might be a good idea to introduce micro-nutrient blended fertilisers in Nepal once more. As the imported, high grade fertiliser from KEMIRA was regarded as expensive, another attempt should include one or both of the fertiliser blending plants which presently are being set up in Terai.

Local knowledge and scientific knowledge.
Every culture has its beliefs of what can be seen as healthy food. A common South Asian perspective is the division into 'hot', 'neutral' and 'cold' foods, which is also found in Nepal (Gittelsohn et al. 1997). The principle is to establish a balance between hot and cold. However, although fruit and vegetables in general are regarded as cold, and animal protein foods are more hot, the local knowledge system is not consistent enough if one tries to translate it into a scientific understanding of content of any specific nutrients, being carbohydrates, protein, vitamins or micronutrients.

The local knowledge system of soil nutrients and plant nutrition in the Nepalese Hills is also inconsistent in some respects. The farmers do have a ranking of the nutrient value of different manures which largely could be said to reflect a scientific ranking based on nitrogen content (Tamang 1993), but the farmers do not have concepts that take into account the peculiarities of specific elements, and certainly not micronutrient deficiencies. They have experienced that use of acidifying fertilisers is making the soils 'sour' and cloddy, and difficult to plough. The terminology applied for different fertilisers among Nepalese farmers are:

-*m__l* - compost/farmyard manure which is perceived as 'the real thing' for plant production
-*fertiliser* - chemical fertiliser, normally 46:0:0 Urea or 18:46:0 DAP
-*vitamin* - any other growth conditioner, plant hormone, micronutrient fertiliser or the like

Nepalese Hill farmers in general often cannot tell whether a plant symptom reflects disease, pest or nutrition problems. Some symptoms of zinc deficiency in rice are referred to as *khaira disease*.

Some of the farmers' techniques do to some extent provide solutions to micronutrient problems. When deficiency symptoms occur in newly planted paddy fields, some farmers temporarily drain the field to permit a partial aeration of the soil which in turn is releasing nutrients. Improved compost management is potentially able to overcome many deficiency problems, and based on field work from Arun Valley (Andersen 2002), it may be suggested that zinc deficiency problems in many or most areas could be eradicated by supplying sufficient amounts of animal bedding to reduce nitrogen losses and promote a good composting process. Two counter-arguments against a too firm belief in local knowledge as the only solution can be presented: 1) if the farmers' knowledge is so good, why do the majority have such a poor compost management? 2) Good composting techniques are not sufficient to cope with serious, regional soil deficiencies such as boron or selenium. These elements have to be supplied from outside, either in fertiliser or animal fodder or some other *input*. A similar point has to be made clear in discussions over Integrated Plant Nutrient Management (IPNM): In the case of severe micronutrient deficiencies, it is *not* enough to combine application of NPK chemical fertiliser with compost/farmyard manure.

In the author's view, the scientific-based knowledge among the farmers has to be improved. Elaboration of appropriate information material is an essential part of this. The use of instructive pictures of visual symptoms should be a powerful tool combined with suggestions of remedies that are available and cost-effective to the farmers. In present information material, no pictures are used, and symptom descriptions like 'interveinal chlorosis' are probably not understood by a majority of farmers. In marginal mountain areas, information based on visual symptoms is more likely to reach many more farmers, than more demanding soil testing and per-crop advice (only few farmers are fertilising for each crop in the annual cycle).

New agricultural extension strategies - a public/private mix.

In a previous paper (Andersen 2002), I 'accused' the Nepal Agricultural Research Council (NARC) of employing '*a rigorous state centric and technocratic attitude to the development of recommendations to farmers'*. This claim may need some further elaboration, not least because new strategies are arising.

Firstly, even in a country with a tradition for strong and hierarchical state control, there is not always a perfect match between different bodies of the administration. NARC is issuing recommendations (or ought to do so), while Dept. of Agriculture is responsible for sending out the extension messages to the farmers. During this course, some recommendations do find their way into extension advices without trials carried out by NARC. Likewise, the open border with India, and the market forces, lead information and farm inputs to find their own ways. However, the flow of technical knowledge from India to Nepal has been quite limited. On the contrary, fertiliser of reasonable quality has been moved from Nepal to India, and poor quality the other way.

Secondly, agricultural policies are changing towards more private involvement. A first meeting between NARC and representatives from the private sector was held in July 2000, aiding the development of new relations within the agricultural sector (Joshi et al. 2000). The para-statal Agricultural Inputs Corporation (AIC) formerly had monopoly over fertiliser supplies, but fertiliser sales have now become deregulated (Basnyat 1999). The Department of Agriculture has started also offering courses in soil fertility and plant nutrition to representatives from the private sector, for instance fertiliser traders. The Fertiliser Unit (FU) at the Ministry of Agriculture has developed information pamphlets on soil fertility to a broad target group. FU has also laid the basis for an improved quality control of imported fertiliser. Among initiatives taken in the private sector, one of the more far-reaching may be the establishment of two fertiliser blending factories in the Terai region.

The basic problem about the state centric model is that it did not work. The public sector in Nepal has neither the resources to carry out field research trials needed for controlling the recommendations, not the extension workers to forward the message to the farmers. Therefore, the ‘public-private mix’ approach may prove a more effective alternative.

Discussion and conclusion.

Micronutrient problems are complicated issues, affected by economic, cultural, agronomic as well as ecological and geological factors. A major part of the evidence behind this paper is from Nepal, but many of the issues may be generalised to marginal regions in many parts of the world.

The strategies suggested by human nutritionists as well as plant breeders or soil scientists have their strengths, but also their weaknesses.

In a marginality perspective, all strategies are likely to work best in urban areas and under better social conditions. Poor populations in remote mountain areas are least likely to receive the benefits of interventions. It may be argued that strategies based on farming systems not are as clearly targeted as for instance medical supplementation to deficient population groups, but two arguments support emphasis on farming system interventions.

Firstly, they are, at least in theory, *more cost-effective*, because they have the potential to (and in fact must) raise the agricultural productivity, and hence create a win-win situation.

Secondly, even if the human nutrition goals are reached through supplementation, fortification or similar interventions, the *plant nutrition and animal nutrition problems still need to be dealt with in order to increase and sustain agricultural yields.* A farming system/food system perspective can be used to assess downstream effects of interventions, and to search for complementary strategies. Improving traditional salt licks for animals can have effects that can be measured in the manure, as well as in the plant, and maybe even in human nutrition. Improved animal mineral supplies may well represent a concentrated input of nutrients that can be transported into remote areas in a cost-effective manner. Successful development of micronutrient efficient crops may solve both human and livestock nutrition problems, but a narrow focus on one crop and one nutrient may have negative side-effects on other crops, or when multiple deficiencies are prevailing.

The traditional top-down approach to agricultural extension is unable to cope with the daily needs of the farmers. Therefore, an enabling strategy is needed, where the knowledge base of the farmers is strengthened, providing new forms of information material, and using new channels for dissemination of knowledge. Pictorial information, based on visual symptoms is one attempt that has potential in semi-literate farming populations. The new public/private approaches emerging in Nepal can be a step in a positive direction, as they are aimed at for instance staff in co-operatives and fertiliser traders, people who are in daily contact with the farmers. New and important roles for the State emerge as suppliers of information, as well as provider of a credible control system for farming inputs in a deregulated regime.

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